DRAFT 10/10/2000

# 5.2 ANALYSIS OF HOURLY FREEWAY ACTIVITY BY DAY-OF-WEEK IN THE SOUTH COAST AIR BASIN DURING THE SUMMER OF 1997

## 5.2.1 Summary

Emissions from on-road mobile sources constitute approximately 50 to 70 percent of both ROG and $NO_x$ emissions in the South Coast Air Basin. Therefore, traffic patterns that differ by day of week (DOW) are expected to be an important cause of the weekend effect.

In this chapter, we analyze hourly traffic patterns by DOW on freeways in Los Angeles and Orange Counties using data collected during the summer of 1997. Freeway traffic by itself constitutes approximately 50% of the vehicle miles traveled (VMT) basinwide.

The hourly traffic patterns by DOW from eleven regions of Los Angeles and Orange Counties lead to several findings. The DOW patterns in all eleven regions are strikingly similar in their general features. Weekday patterns are similar to each other and the shape of the Saturday and Sunday patterns are similar to one another.

Traffic between 5 a.m. and 11 a.m. is substantially lower on weekends compared to weekdays, with the greatest hourly reductions reaching 50 to 60 percent on Saturday and 70 to 80 percent on Sunday.

On weekends after 11 a.m., the traffic is similar to weekday traffic in some regions. In other regions, however, a strong evening commute causes weekend traffic to be as much as 30 percent lower than weekday traffic during some hours.

Though traffic patterns may differ between regions, hourly profiles are similar for all weekdays within regions. Some regions have high afternoon volumes during p.m. commute hours on weekdays, while in other regions the increase is less pronounced.

Traffic is relatively high in all regions between 9 p.m. on Friday and 5 a.m. on Saturday and between 9 p.m. on Saturday and 5 a.m. on Sunday. During these periods, the increase compared to weekdays reaches 60 to 100% around 3 a.m.

During daylight hours, traffic volumes on freeways tend to be lowest on Sunday. Between 11 a.m. and 2 p.m., however, the volumes on Sunday may be similar the volumes on other days. Saturday profiles are similar to Sunday though somewhat higher for almost all hours of the day. Though higher than Sunday, Saturday morning traffic is lower than weekday traffic between 5 a.m. and 11 a.m. in all regions.

Based on these analyses, we find that both the total volume of traffic and the timing of traffic are significantly different on weekends compared to weekdays. The circumstantial observations are consistent with Hypothesis #1, #2, #3, and #5. The freeway data offer little insight concerning Hypothesis #4.

### 5.2.2 Introduction

Emissions from on-road mobile sources constitute a large fraction of the total emissions inventory throughout California. In the South Coast Air Basin, on-road mobile sources produce approximately 50 to 70 percent of ROG and NOx emissions depending on the model used to estimate emissions. Therefore, understanding the weekend effect requires a thorough investigation of hourly traffic patterns by day-of-week (DOW).

In this chapter, we analyze hourly traffic patterns by DOW on freeways in Los Angeles County and Orange County using data collected during the summer of 1997. Freeway traffic accounts for approximately half of the total vehicle miles traveled (VMT) with the remaining portion occurring on surface streets. Unfortunately, the data available for surface streets is quite limited at this time. Nevertheless, a thorough analysis of the freeway traffic patterns is an important milestone in research on the weekend effect.

### 5.2.3 Methodology

#### 5.2.3.1 Data

Traffic managers in Los Angeles and Orange Counties use data from a CALTRANS network of inductive-loop sensors that gather traffic data continuously. The purpose of this real-time network is to support a rapid response to accidents and other events that impede the smooth flow of traffic on the region's freeways.

Vehicle counts by lane are collected in 30-second increments, but the 30-second data are not archived routinely. By special arrangement, the 30-second data during the recent South Coast Ozone Study (SCOS97 - June 15 through October 10, 1997) were archived on tape for further analysis. As part of a separate project, Dr. Niemeir at U.C. – Davis transferred the data from many tapes to a more convenient form. Copies of the data files were given to us on a set of compact discs, which we used for our independent analyses.

#### 5.2.3.2 Regions selected for analysis

Eleven regions, or domains, of Los Angeles and Orange Counties were selected for analysis of freeway traffic. Each region is associated with an air quality monitor to allow comparisons between hourly profiles for traffic and hourly profiles for ozone precursors (see Section 5.3). Table 5.2.1 lists the selected regions along with some of their characteristics. Figure 5.2.1 – Figure 5.2.12 show the selected domains.

#### 5.2.3.3 QA/QC and data summary procedures

In each region, we selected counters (sites) that cover both sides of a freeway. This procedure maintains a balance, appropriately representing the traffic on both sides of a freeway. For example, sites on the "inbound" and "outbound" sides of a freeway will be balanced throughout the day.

The following QA/QC procedure was used to validate the data selected for these analyses. The criteria listed below were applied to the data for each lane at each site by DOW. The criteria were applied in the sequence shown here:

- Counts were aggregated to 10-minute intervals.
- Zero counts were invalid (set to “missing”).
- Counts greater than 600 were invalid (set to “missing”).
- Data were invalid for a whole day if the day’s maximum 10-minute count < 20.
- Data failing a comparison to a median value were invalid.
- If a 10-minute period had less than four valid days, the average value for that 10-minute period was invalid.
- Any lane with an invalid average for a 10-minute period was invalid for all 10-minute periods.

Inductive loop counters typically yield highly accurate counts based on ground truth comparisons (Klein, 1997). When they fail, however, the dominant failure mode is to cease detecting vehicles entirely and report “zero” traffic. The traffic data we analyzed exhibits these characteristics.

Zeroes often represent invalid data but zeroes cannot be automatically excluded from the data sets because they are reasonable values for 30-second intervals. However, zeroes are not reasonable values for 10-minute periods. Therefore, we aggregated the 30-second counts to form counts for 10-minute periods; zeroes for the 10-minute periods were invalidated.

Although an inductive loop counter may characterize the traffic flow accurately, the count may under-represent some of the activity, such as engine idling, that produces emissions. Figure 5.2.13 shows the generic relationship between flow (x-axis) and average travel speed (y-axis). As the density of vehicles increases, the flow also increases up to a limit. When the density exceeds approximately 60-70 vehicles per lane per mile (60 to 75 feet between vehicles), the flow begins to decrease (Highway Capacity Manual, 1985, pp 3-4 and 3-5). The inductive loop counters detect flow rather than density. Therefore, under extreme density conditions, the counts may understate the true emissions due to vehicles on the freeways.

The implications of the preceding paragraph may be different for different pollutants. Both the US-EPA and the CARB carried out emissions tests using driving cycles (speed-time traces) based on freeway conditions at different densities/speeds. These tests indicate that hydrocarbon emissions per mile traveled <u>increase</u> rapidly as average speeds <u>decrease</u> from 40 mph toward zero mph. $NO_x$ emissions per mile, however, tend to <u>decrease</u> as average speeds <u>decrease</u> down to approximately 5 mph at which point the $NO_x$ emissions increase again.

Tests using driving cycles that represent surface streets have shown that the relationship of hydrocarbon emissions to speed is similar to that for freeways. The relationship of $NO_x$ emissions to speed, however, seems to be the opposite of that for freeways. The tests for surface streets indicate that $NO_x$ emissions per mile <u>increase</u> continuously as speeds <u>decrease</u> from 40 mph toward zero.

Traffic counts greater than 30 vehicles in 30 seconds can be valid based on personal observations on a Sacramento freeway overpass. For example, a density of 60 vehicles per lane per mile with traffic moving at 60 miles per hour would yield counts of 30 vehicles in 30 seconds. However, this density corresponds to a category E for “level of service,” during which a 60 mph average speed cannot be sustained for long (Transportation Research Board, 1994). Therefore, all 10-minute counts greater than 600 were invalidated. It is not clear that any 10-minute counts were excluded by applying this criterion.

If the maximum 10-minute count for a day was less than 20 vehicles, the entire day was invalid. This criterion addresses a failure mode for the counters in which low but non-zero counts are recorded. For example, a sequence of 30-second counts might look like this: 0, 0, 2, 1, 0, 0, 0, 3, 1. Although such a sequence is reasonable between 2 a.m. and 3 a.m., it is not a reasonable pattern throughout an entire day. Therefore, if the maximum 10-minute count for a day was less than 20 vehicles, it indicated that the detector is faulty and data for the whole day were invalid.

We compared the 10-minute counts to their corresponding median values (same DOW and same 10-minute period) to help eliminate invalid counts. A 10-minute count is the sum of twenty 30-second counts. Occasionally, some 30-second counts may be invalid zeroes. Because induction-loop counters tend to work continuously or fail continuously for long stretches, however, most 10-minute periods contain either all valid data or all invalid data. At this point in the validation process, few values based entirely on invalid data will remain in the database. Furthermore, it is quite unlikely that the identical two 10-minute periods on two different Mondays (or some other DOW) will both contain a mix of valid and invalid data. Therefore, the median of the 10-minute observations (for a lane for a DOW) should represent the valid data well. Therefore, if a 10-minute count differed from its respective median by more than 2/3 of the corresponding median value, that 10-minute count was invalid.

A valid <u>average</u> for a 10-minute period (for a lane for a DOW) required at least four valid 10-minute periods. Although this is a small sample size in many situations, in this case it seems to be satisfactory. This is because the valid counts for the same lane, 10-minute period, and DOW combination are very similar to one another (the variability is small). For example, the counts between 11:00 a.m. and 11:10 a.m. for a particular lane on two different Mondays are almost always within 10 percent of each other.

Keeping the valid lanes at a site allowed these lanes to represent the site effectively. As a final step, we included pairs of sites in the analysis only if they had the same number of valid lanes. This approach is suitable for comparing traffic patterns by DOW in relative terms, but it undercounts the actual volume of traffic due to the missing lanes. For our purposes, however, the <u>relative</u> activity by DOW is satisfactory.

Using the preceding criteria, a valid average count for each 10-minute period for each DOW was based on at least 4 days of data.

Keeping the valid lanes at a site allowed these lanes to represent the site effectively. As a final step, we included pairs of sites in the analysis only if they had the same number of valid lanes. This approach is suitable for comparing traffic patterns by DOW in relative terms, but it undercounts the actual volume of traffic due to the missing lanes. For our purposes, however, the relative activity by DOW is satisfactory.

If invalid data remained in the data after executing the validation procedure, their impact on the final analyses is almost certainly quite small. Most of the invalid values are removed at the 10-minute level. If an invalid 10-minute observation remains, it will be averaged with at least three other observations that are probably valid. That average will then be summed with five other averages to make an average hourly total for a lane and for a DOW. Next, the lane total will be summed with the totals for the other lanes to make an hourly total at the site for a DOW. Finally, the hourly average totals for all the selected sites in a given region are summed to represent the total traffic. These sums are used for subsequent analyses. Because any invalid data are highly diluted with valid data, bias (distinct from random variability) in the values used in the final analyses should be limited to a few percent.

#### 5.2.3.4 Presentation techniques

We conducted two summaries for each region. First, we compiled the hourly profiles for total volume by DOW. Second, we expressed the hourly volumes as ratios with respect to the midweek average (Tuesday through Thursday). The results are presented in tabular form in Appendix C. Here in this section, we present the results graphically. For each domain, we present two graphs. The first graph displays the total vehicle count per hour, while the second graph shows the relative vehicle count with respect to the midweek average. The graphs are labeled Figure 5.2.14 through Figure 5.2.35. The graphs are somewhat simplified for readability, while the tables in Appendix C retain the full details.

### 5.2.4 Results and Discussion

We analyzed the hourly traffic patterns by DOW for each region. The results are discussed first in terms of general patterns and then with respect to differences between regions.

#### 5.2.4.1 General Patterns in the Freeway Data

The hourly traffic profiles in all eleven regions are strikingly similar in their general features. The most obvious and anticipated pattern is that weekdays look like weekdays, weekends look like weekends, and weekdays are not like weekends.

Within each region, Monday through Friday profiles have a similar overall shape. The morning commute period on these days commences at the same time and reaches its peak at the same time. The traffic during the mid-day and afternoon hours is also similar for all weekdays. With the exception of the late evening hours on Friday, the night and evening profiles also are similar for the weekdays.

The Saturday and Sunday profiles have a similar general shape. The morning commute (6 a.m. to 10 a.m.) on weekdays is absent on both Saturday and Sunday. The weekday traffic is as much as 50 to 60 percent greater than Saturday and 70 to 80 percent greater than Sunday for some morning hours.

The peak traffic on weekend days is typically achieved between noon and two o'clock. Although similar in general shape, the Saturday volumes are greater than the corresponding Sunday volumes during most of the daylight hours in all regions.

In all regions, traffic on Friday evening between 9 p.m. and midnight is relatively high and this phenomenon continues into Saturday morning until 5 a.m. The scenario is repeated from 9 p.m. Saturday to 5 a.m. on Sunday. The relative increases on Saturday and Sunday reach 60 to 100% around 3 a.m. Though the relative increase is large, the volumes involved are rather small compared to traffic during most of the daylight hours.

#### 5.2.4.2 Regional Differences

Hourly profiles for all weekdays are very similar within a region. Some regions, such as Azusa, Burbank, and N. Long Beach, display sharp peaks during both the morning and afternoon commute hours on weekdays. In other regions, such as Anaheim, Lynwood, and Pico Rivera, the morning commute has a sharp peak and the afternoon commute has a broader peak that is slightly lower than the morning peak.

On weekends after 11 a.m., traffic volumes are similar to weekdays in some regions. These regions tend to be those that lack a sharp peak for the afternoon commute. In the other regions, a strongly peaked commute pattern between 3 p.m. and 7 p.m. causes weekend traffic to be as much as 30 percent lower than weekday traffic during some of these hours.

### 5.2.5 Conclusions

Our analyses demonstrate that the hourly patterns of freeway traffic by day-of-week are generally similar throughout Los Angeles and Orange Counties. Both the <u>total volume of traffic</u> and the <u>timing of traffic</u> are dramatically different on weekends compared to weekdays. Unless traffic on surface streets runs counter to traffic on freeways, the total emissions of VOC's and $NO_x$ from on-road mobile sources should be much lower on weekends. These observations lend circumstantial support to Hypothesis #1 and Hypothesis #2.

The data also offer some support for Hypothesis #3. On freeways at least, the nighttime traffic on Fri/Sat and on Sat/Sun is greater than on other nights. This is true for all of the regions we considered. Therefore, one might reasonably expect greater concentrations of VOC's and $NO_x$ on Saturday and Sunday mornings. If so, the availability of these precursors could give an early boost to ozone formation on weekends.

### 5.2.6 Recommendations

Although the freeway traffic data used in this section has been very useful, three factors limited the extent of the analyses and conclusions. First, the data do not address traffic on surface streets. Second, the data cannot be disaggregated hourly by type of vehicle. And third, the data do not cover the portions of Riverside and San Bernardino Counties in the SoCAB. The recommendations follow directly.

- Collect hourly traffic on surface streets for all days of the week with information on vehicle type.
- Collect hourly freeway traffic with information on vehicle type.
- Collect both freeway and surface street information throughout the SoCAB.

### 5.2.7 References

Lawrence A. Klein, "Vehicle Detector Technologies for Traffic Management Applications, Part 2," at ITS Online, 1997. (http://www.itsonline.com/detect_pt2.html)

Transportation Research Board, "Highway Capacity Manual," National Academy of Sciences, Washington, D.C., 1994.

## Table 5.2.1 Regions Selected for Analysis of Freeway Traffic by Day of Week

| Name of Region | Freeways Involved | No. of Counters | Area (approx.) |
|---|---|---|---|
| Anaheim | I-5, SR-57, and SR-91 | 12 | 16 sq. mi. |
| Azusa | I-605, I-210, and I-10 | 20 | 30 sq. mi. |
| Burbank | I-5 and SR-134 | 18 | 12 sq. mi. |
| Hawthorne | I105 and I-405 | 12 | 12 sq. mi. |
| Irvine | I-405 | 12 | 12 sq. mi. |
| Los Angeles – CBD | I-5, I-10, SR-110, and US-101 | 20 | 16 sq. mi. |
| Lynwood | I-105 | 12 | 12 sq. mi. |
| N. Long Beach | I-405, I-710, and SR-91 | 6 | 12 sq. mi. |
| Pico Rivera | I-5 and I-605 | 8 | 12 sq. mi. |
| Pomona | I-10 and SR-57 | 18 | 16 sq. mi. |
| Reseda | I-405 and US-101 | 14 | 30 sq. mi. |

## Table 5.2.2 Volume Relative to Midweek by Region and Day of Week

| | Day of Week | | | | | | |
|---|---|---|---|---|---|---|---|
| Region | Sun | Mon | Tue | Wed | Thu | Fri | Sat |
| Anaheim | 79.6% | 95.0% | 99.0% | 99.5% | 101.5% | 98.6% | 92.7% |
| Azusa | 75.4% | 97.3% | 98.8% | 100.0% | 101.2% | 100.6% | 86.4% |
| Burbank | 75.2% | 98.1% | 99.0% | 99.6% | 101.4% | 102.1% | 86.9% |
| Hawthorne | 79.3% | 98.8% | 99.3% | 99.6% | 101.1% | 100.4% | 89.0% |
| Irvine | 71.4% | 93.2% | 99.1% | 99.9% | 101.0% | 99.0% | 85.6% |
| L.A.-CBD | 82.6% | 97.0% | 99.2% | 99.7% | 101.1% | 101.6% | 95.3% |
| Lynwood | 81.9% | 98.6% | 99.2% | 99.7% | 101.1% | 101.8% | 93.3% |
| N. Long Beach | 65.5% | 97.0% | 98.1% | 100.3% | 101.5% | 100.2% | 77.5% |
| Pico Rivera | 84.4% | 99.4% | 99.0% | 99.2% | 101.7% | 101.3% | 95.8% |
| Pomona | 81.0% | 98.8% | 98.7% | 99.8% | 101.5% | 101.5% | 91.3% |
| Reseda | 80.6% | 98.8% | 98.9% | 99.6% | 101.5% | 99.4% | 90.0% |
| Average | 77.9% | 97.5% | 98.9% | 99.7% | 101.3% | 100.6% | 89.4% |

**Figure 5.2.1 Basinwide perspective of the locations of 11 domains selected for analysis of freeway traffic counts**

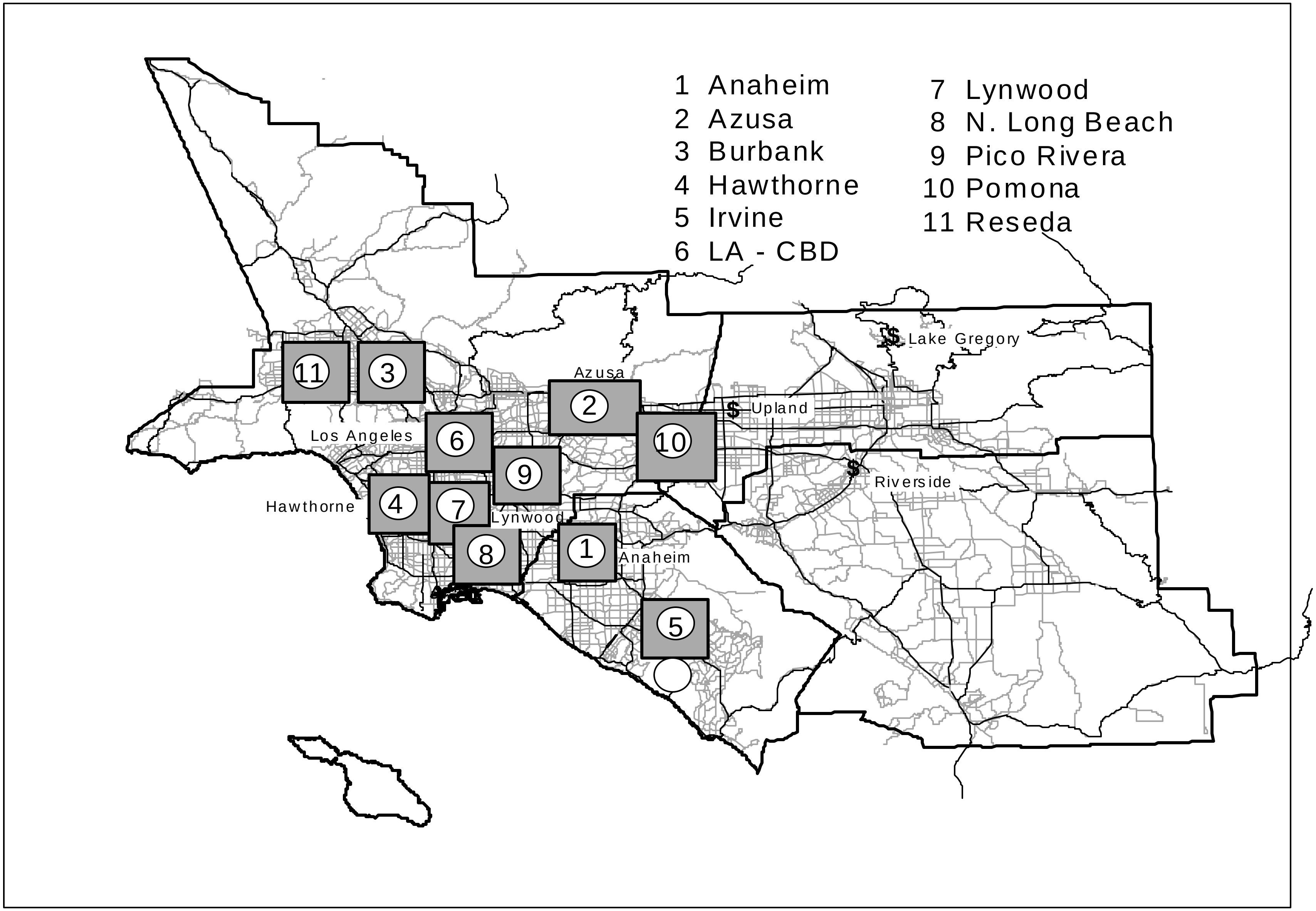

**Figure 5.2.2 Anaheim domain: the solid circles show locations of freeway traffic counters and the solid triangle indicates the air quality monitor**

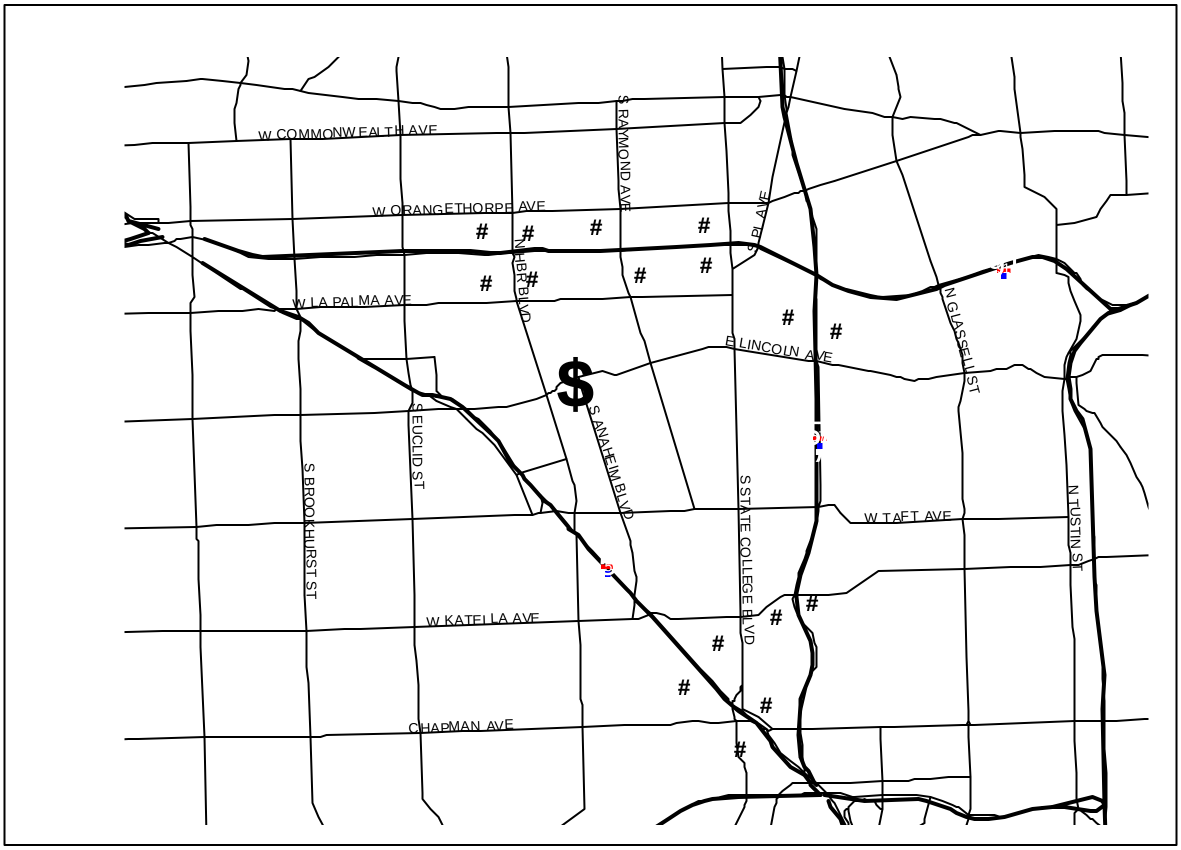

**Figure 5.2.3 Azusa domain: the solid circles show locations of freeway traffic counters and the solid triangle indicates the air quality monitor**

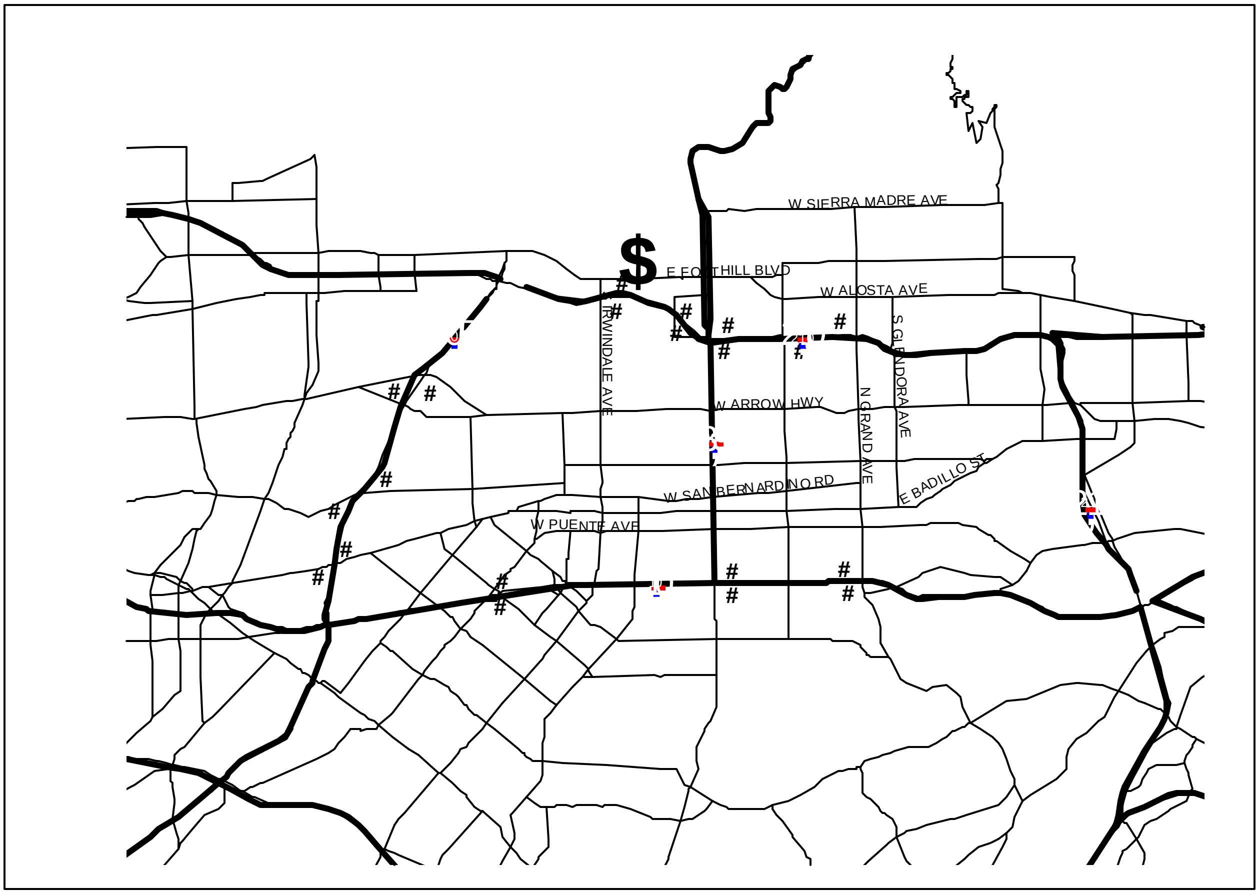

**Figure 5.2.4 Burbank domain: the solid circles show locations of freeway traffic counters and the solid triangle indicates the air quality monitor**

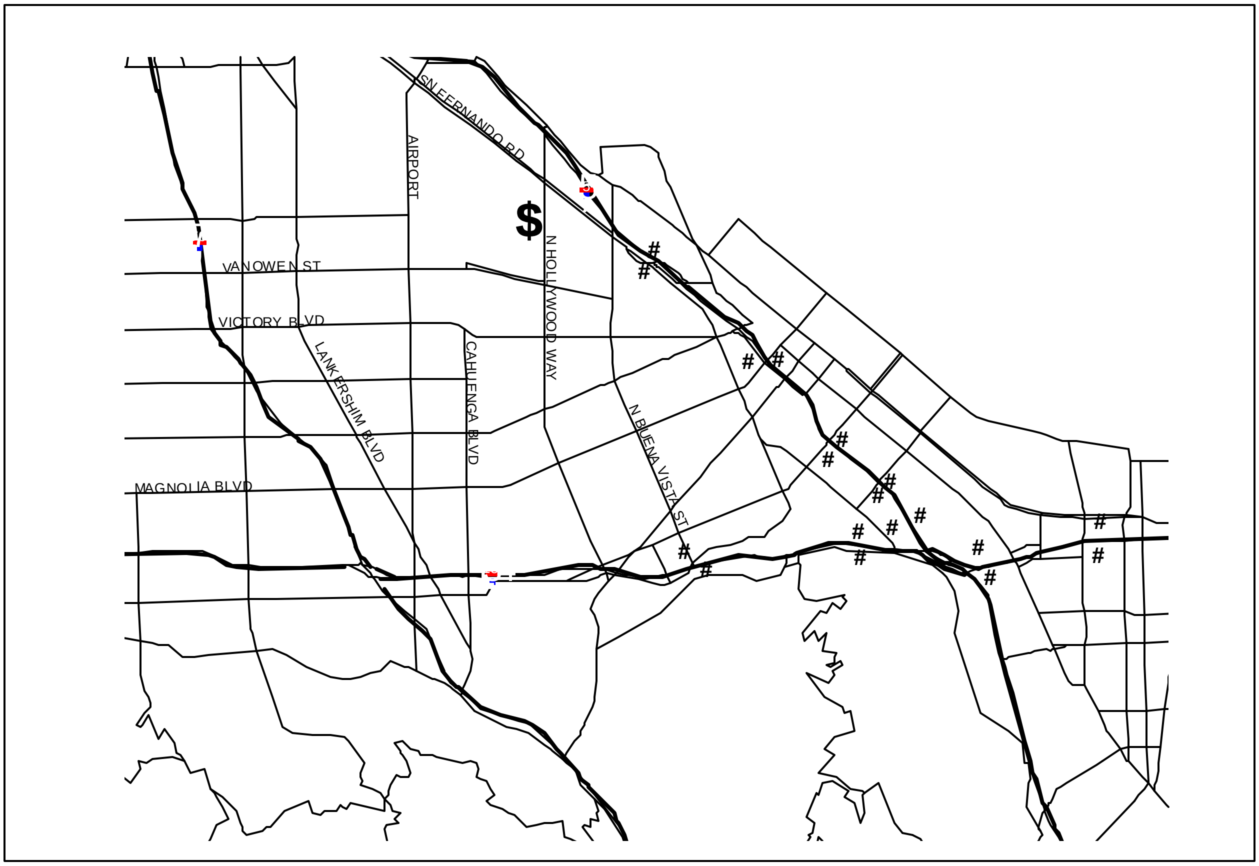

**Figure 5.2.5 Hawthorne domain: the solid circles show locations of freeway traffic counters and the solid triangle indicates the air quality monitor**

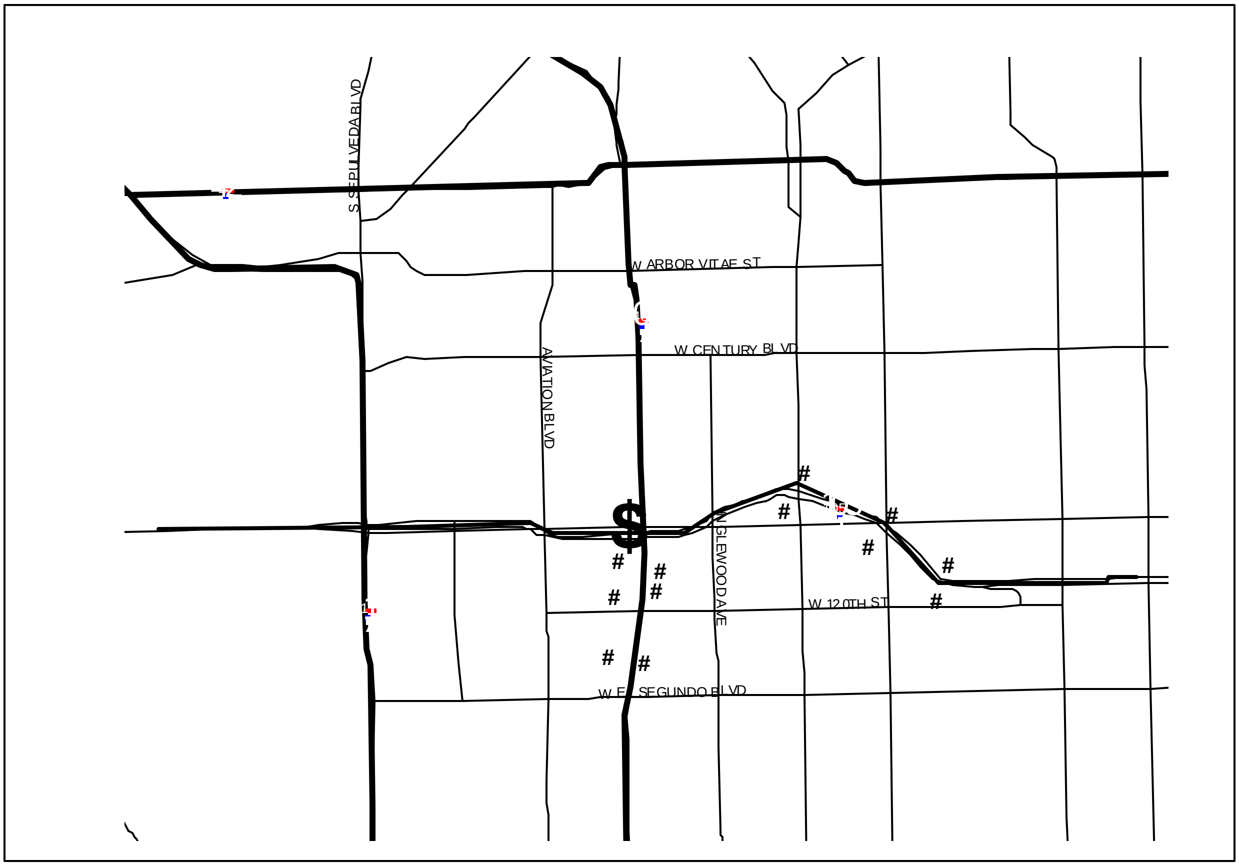

**Figure 5.2.6 Irvine domain: the solid circles show locations of freeway traffic counters and the solid triangle indicates the air quality monitor**

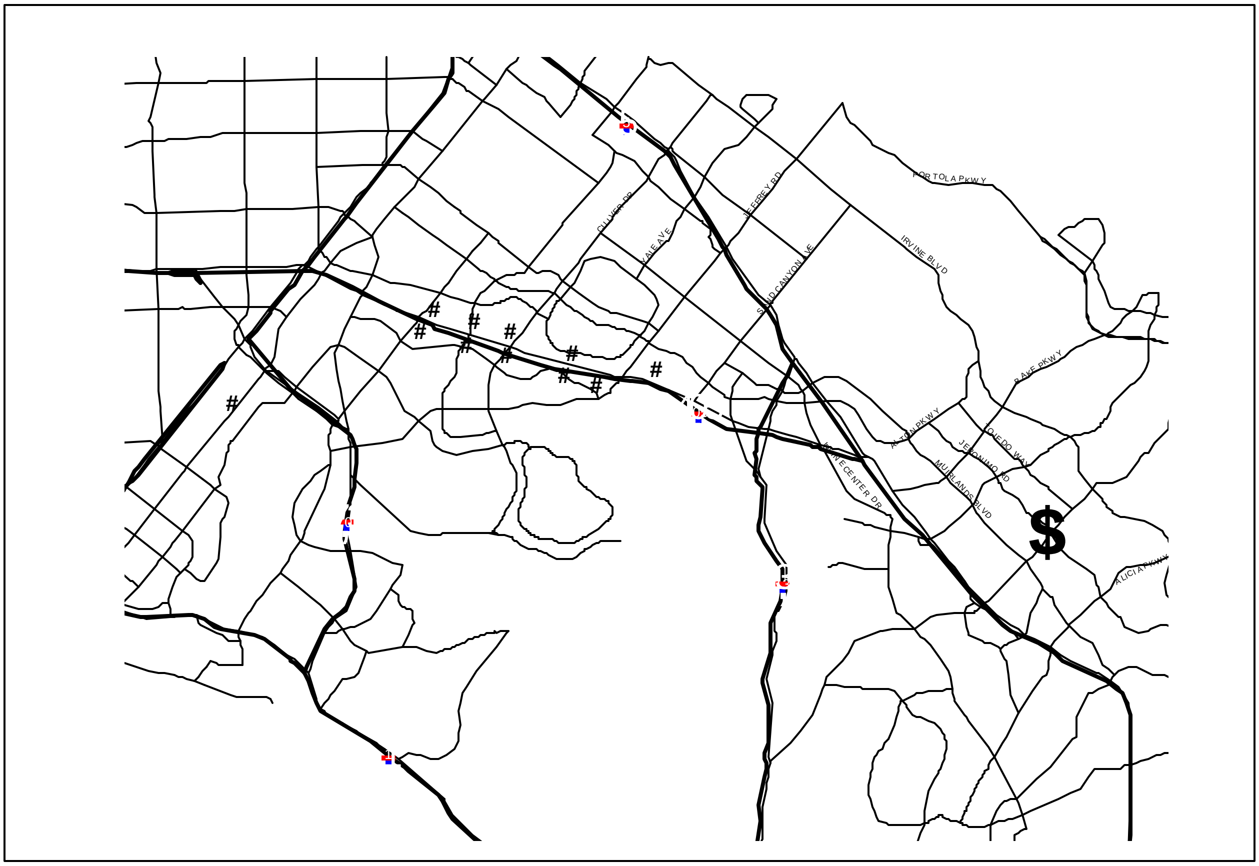

**Figure 5.2.7 LA-CBD domain: the solid circles show locations of freeway traffic counters and the solid triangle indicates the air quality monitor**

**Figure 5.2.8 Lynwood domain: the solid circles show locations of freeway traffic counters and the solid triangle indicates the air quality monitor**

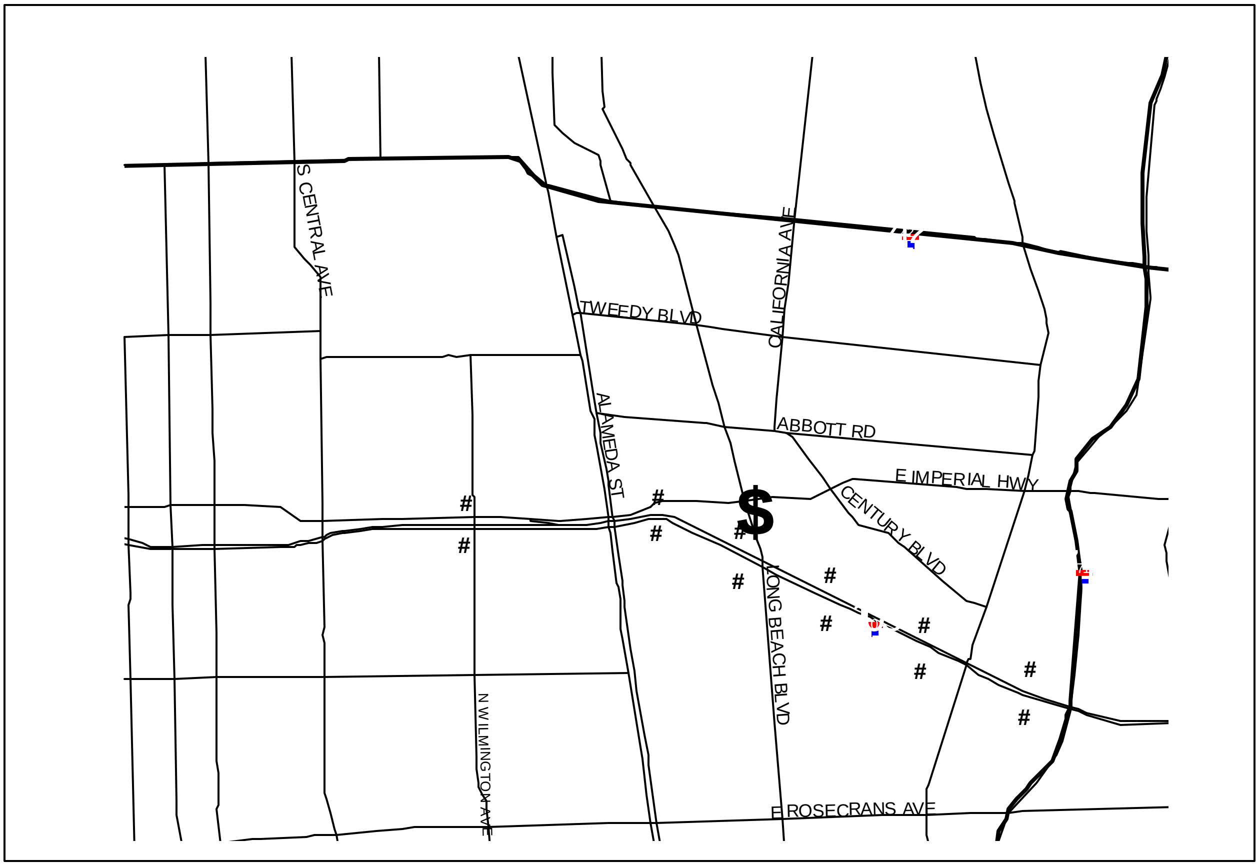

**Figure 5.2.9 N. Long Beach domain: the solid circles show locations of freeway traffic counters and the solid triangle indicates the air quality monitor**

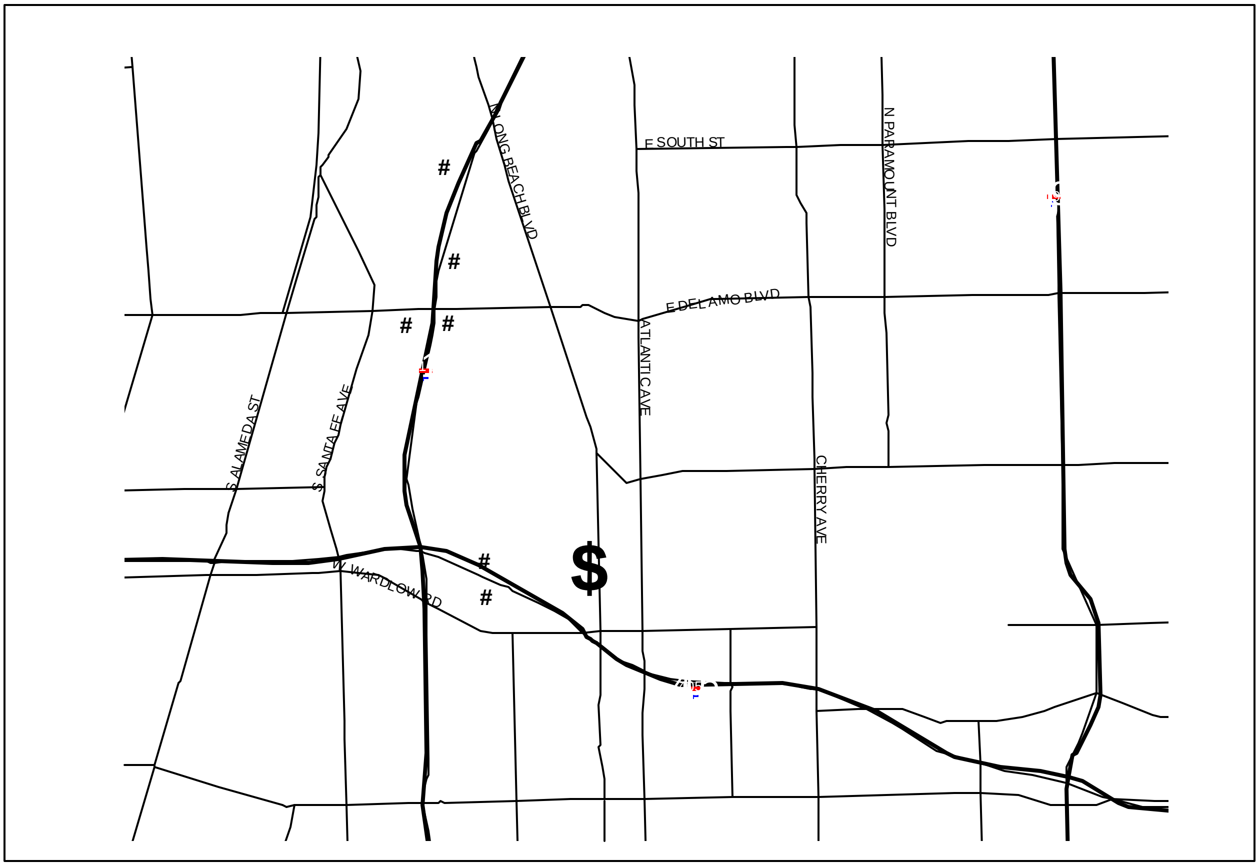

**Figure 5.2.10 Pico Rivera domain: the solid circles show locations of freeway traffic counters and the solid triangle indicates the air quality monitor**

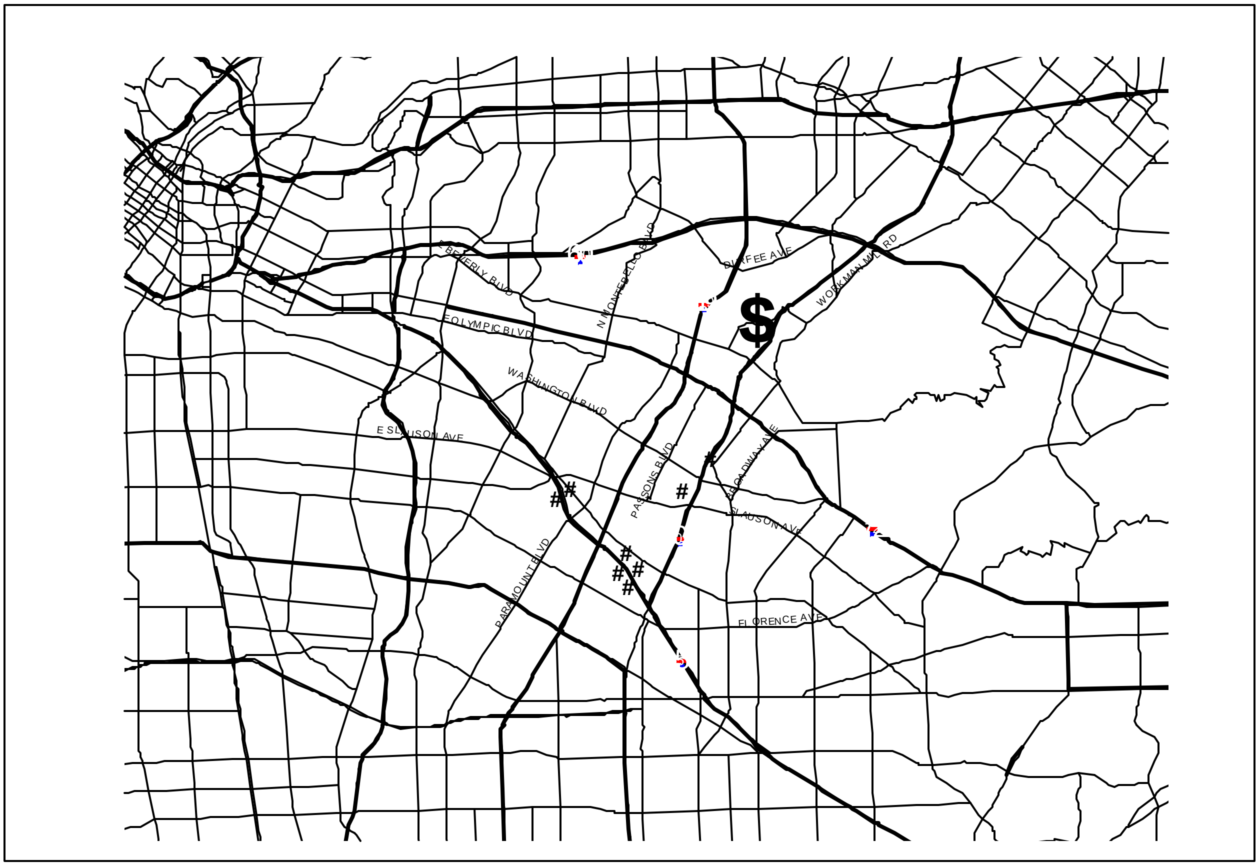

**Figure 5.2.11 Pomona domain: the solid circles show locations of freeway traffic counters and the solid triangle indicates the air quality monitor**

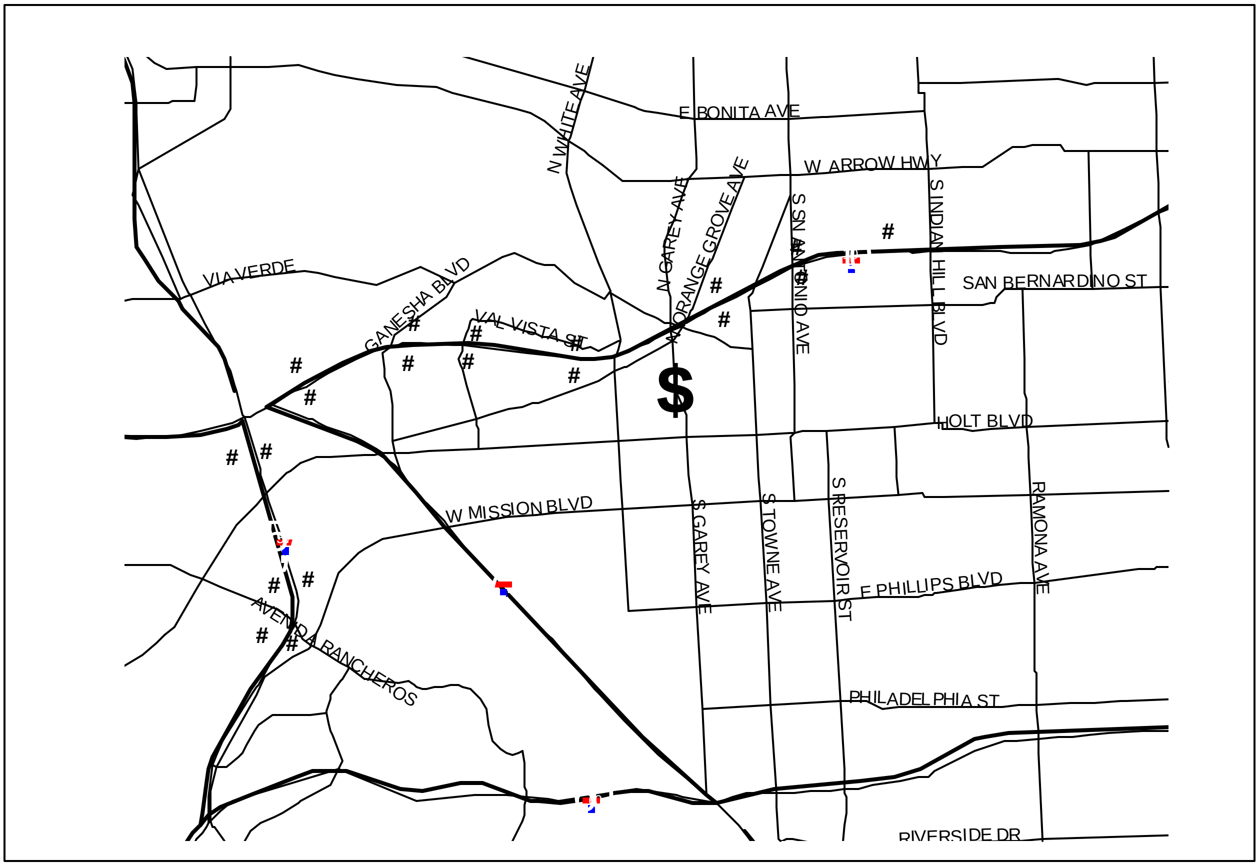

**Figure 5.2.12 Reseda domain: the solid circles show locations of freeway traffic counters and the solid triangle indicates the air quality monitor**

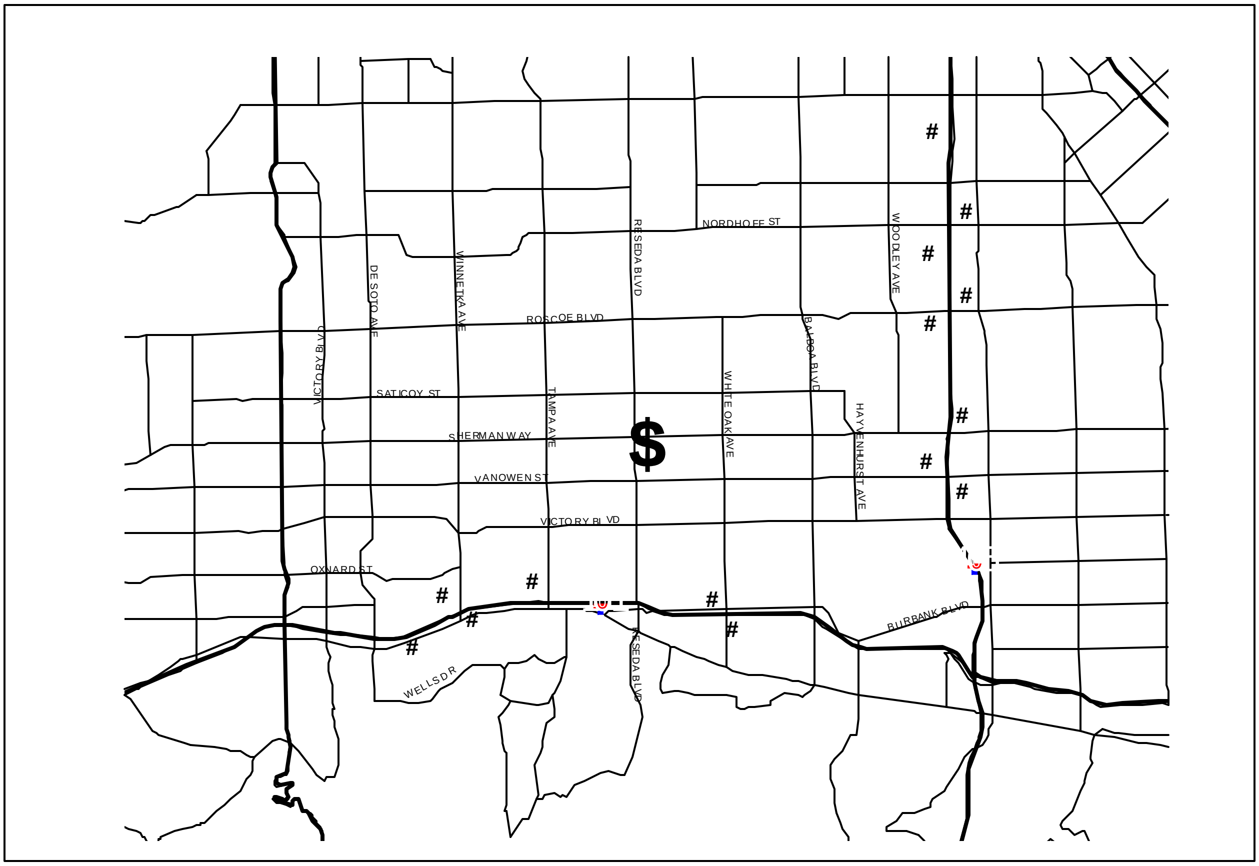

**Figure 5.2.13 Generic speed-flow relationship for freeways under ideal conditions**

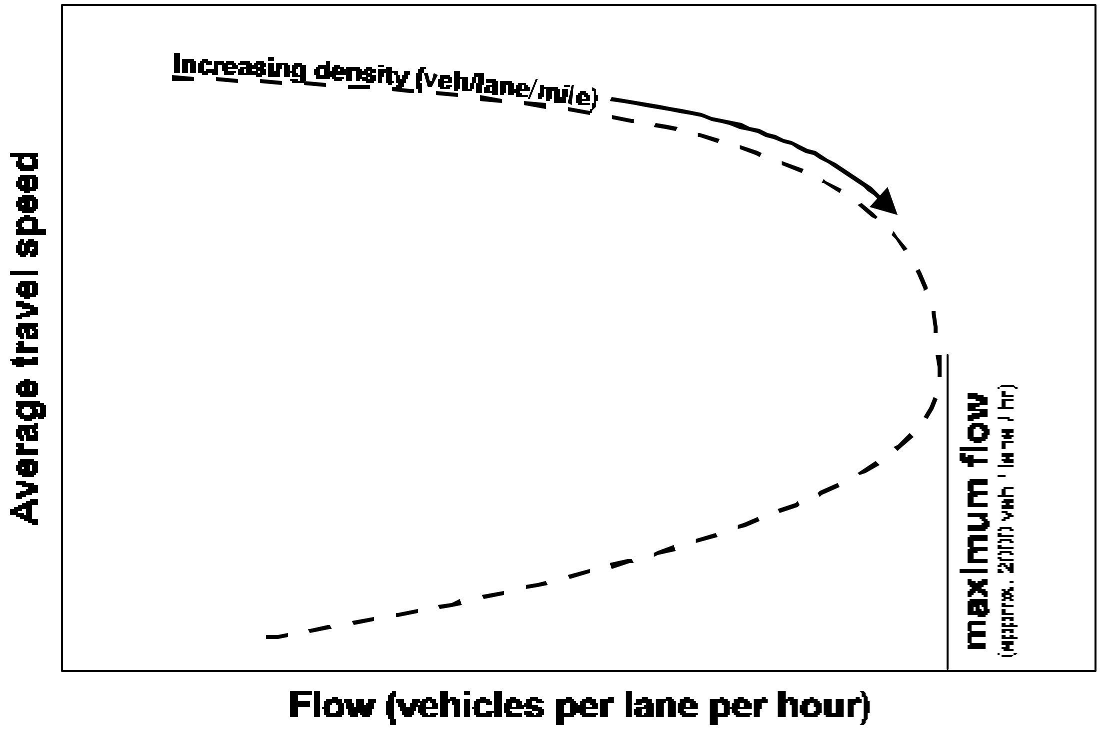

**Figure 5.2.14 Total Volume from Selected Counters in the Anaheim Domain**

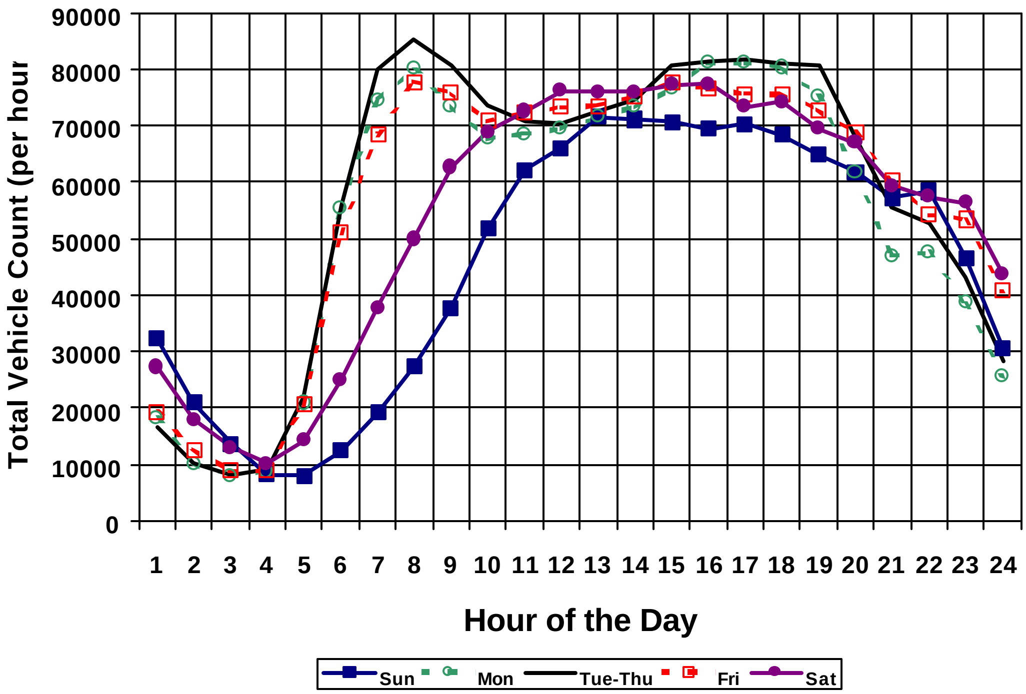


**Figure 5.2.15 Volume Relative to Midweek in the Anaheim Domain**

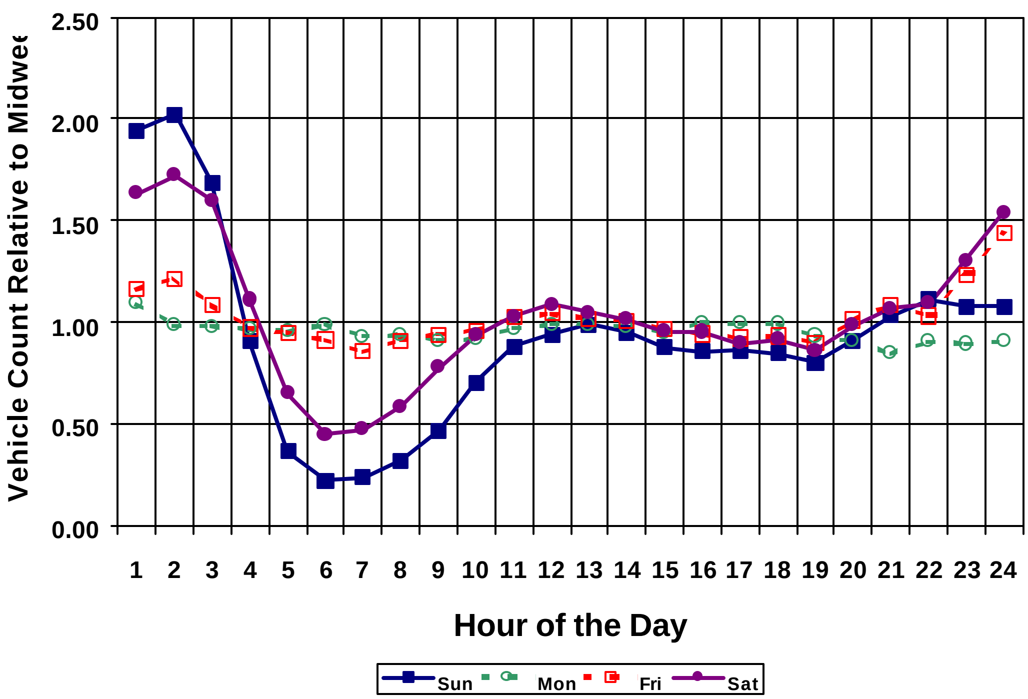

Figure 5.2.16 Total Volume from Selected Counters in the Azusa Domain

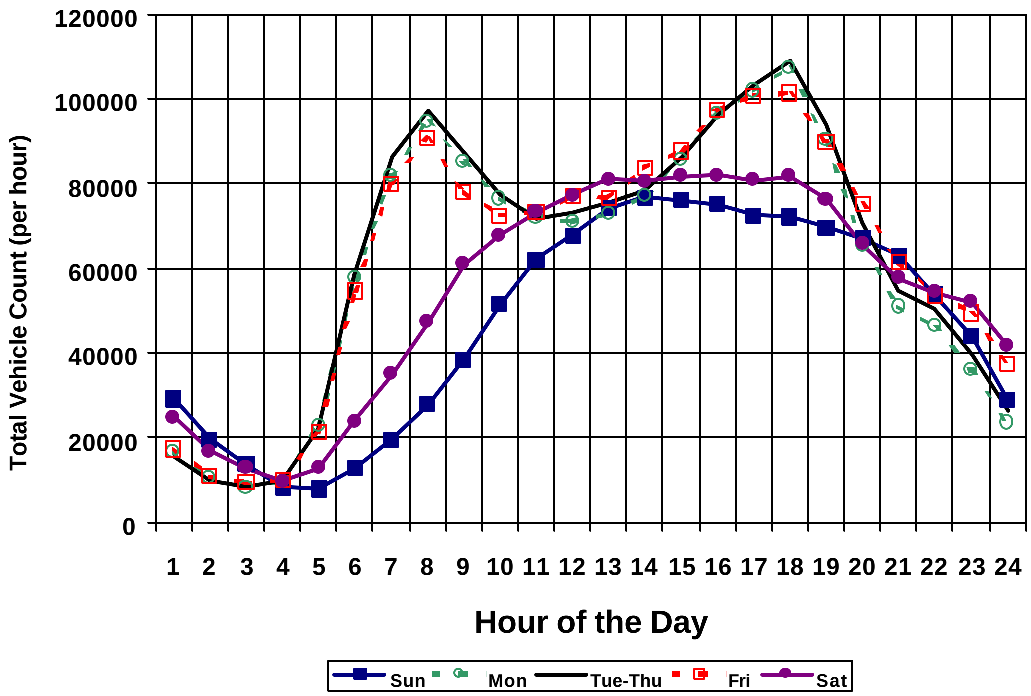


Figure 5.2.17 Volume Relative to Midweek in the Azusa Domain

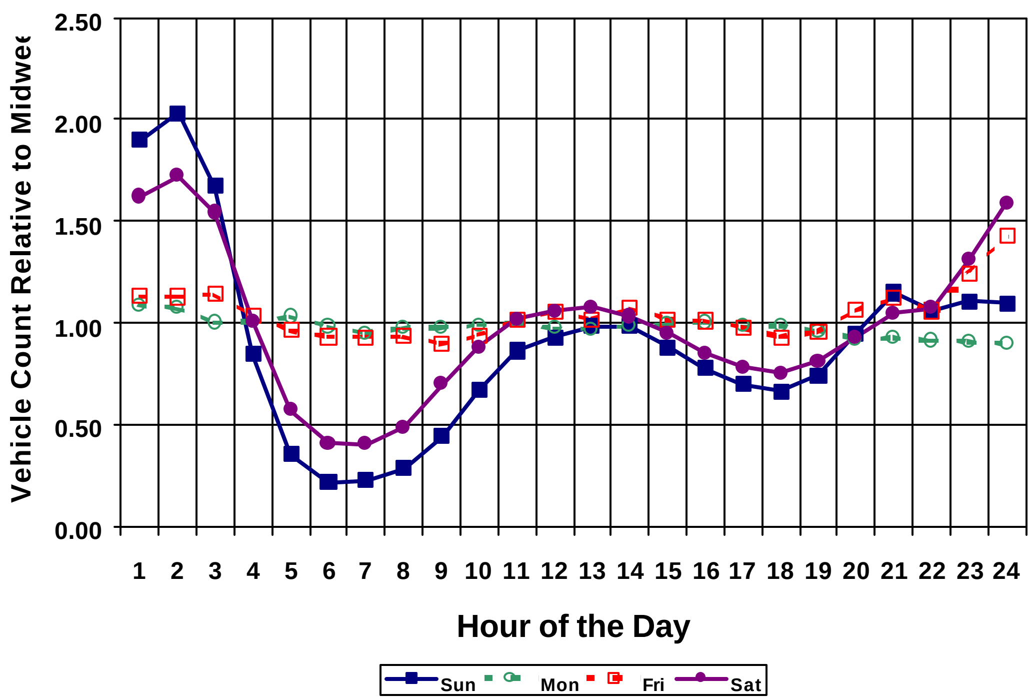

**Figure 5.2.18 Total Volume from Selected Counters in the Burbank Domain**

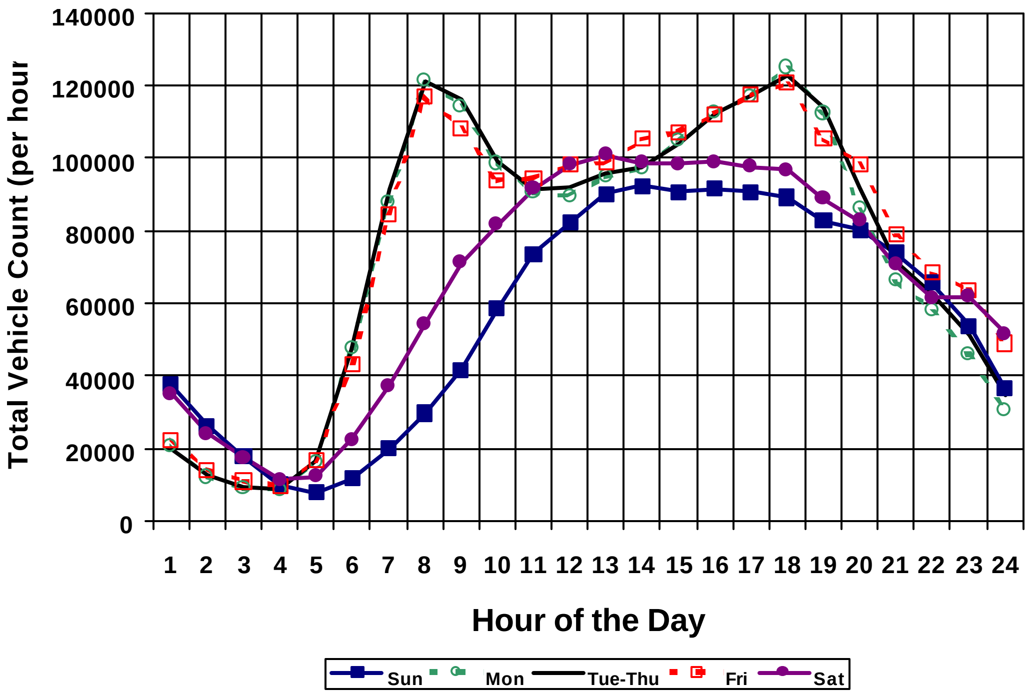


**Figure 5.2.19 Volume Relative to Midweek in the Burbank Domain**

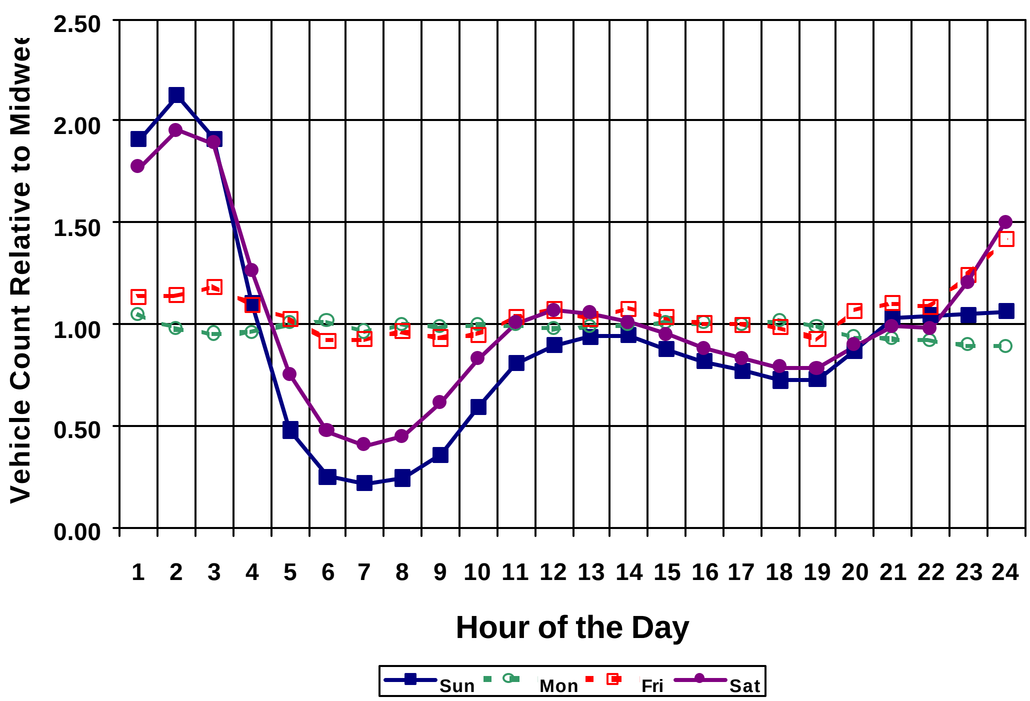

**Figure 5.2.20 Total Volume from Selected Counters in the Hawthorne Domain**

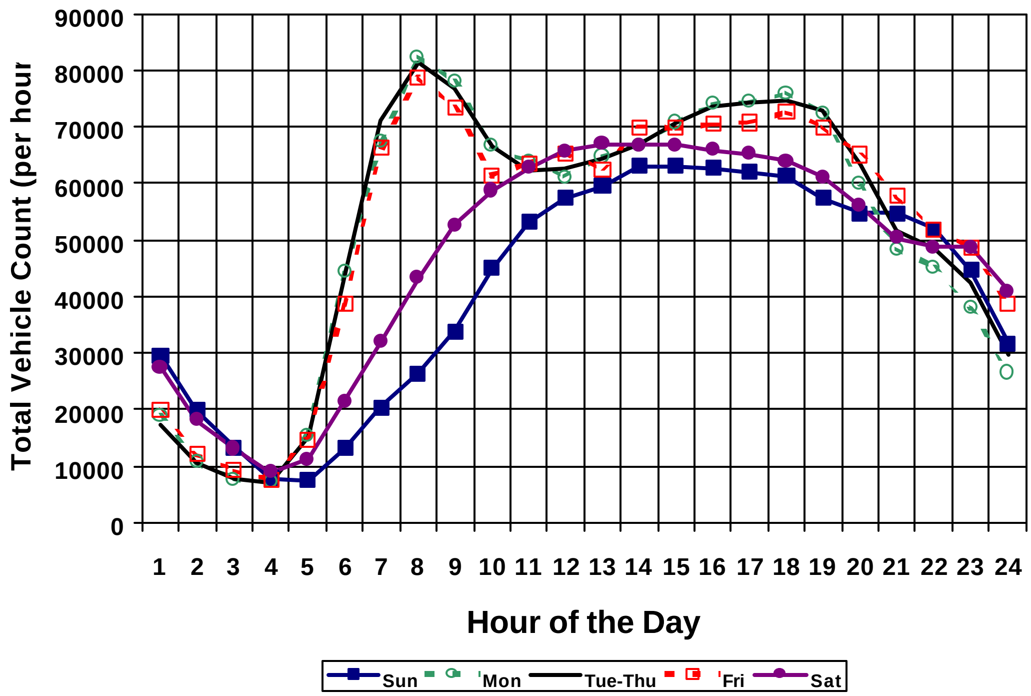


**Figure 5.2.21 Volume Relative to Midweek in the Hawthorne Domain**

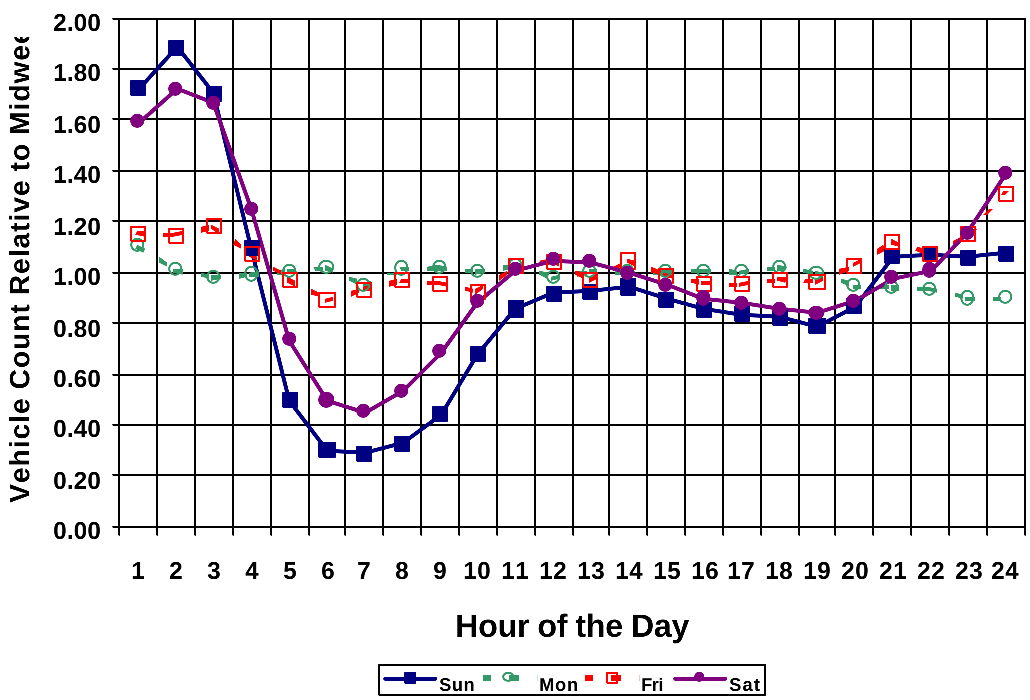

**Figure 5.2.22 Total Volume from Selected Counters in the Irvine Domain**

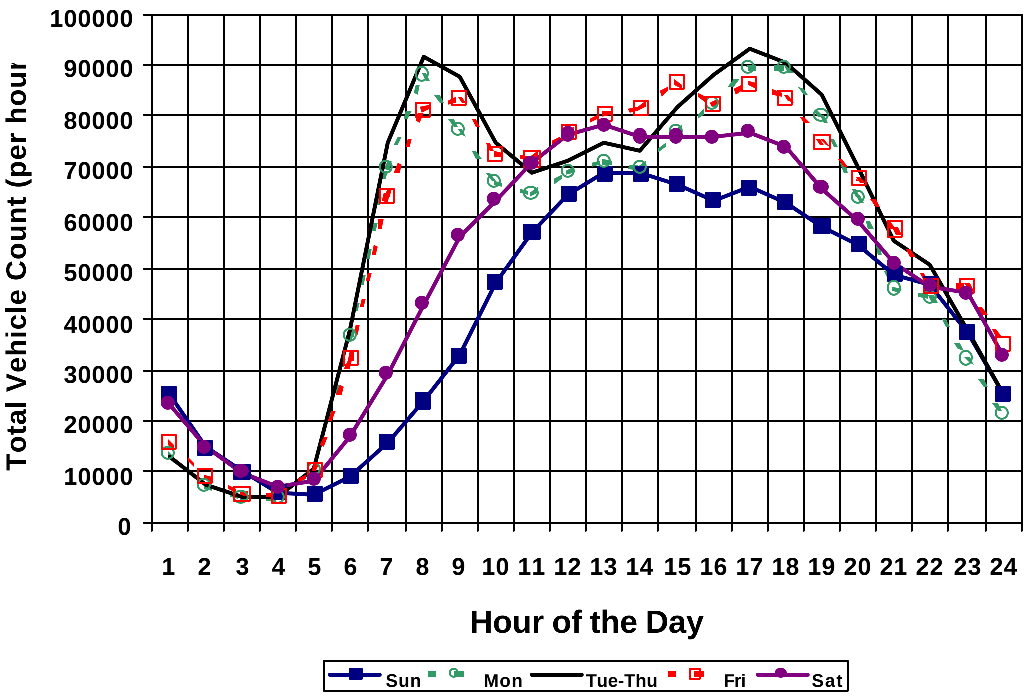


**Figure 5.2.23 Volume Relative to Midweek in the Irvine Domain**

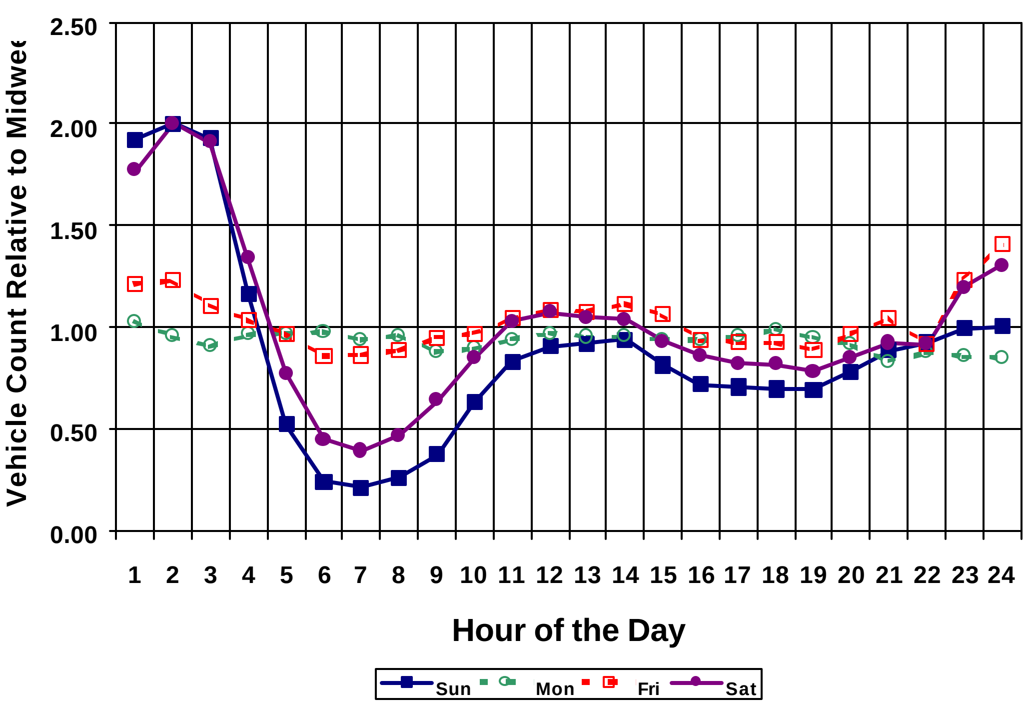

**Figure 5.2.24 Total Volume from Selected Counters in the L.A-CBD Domain**

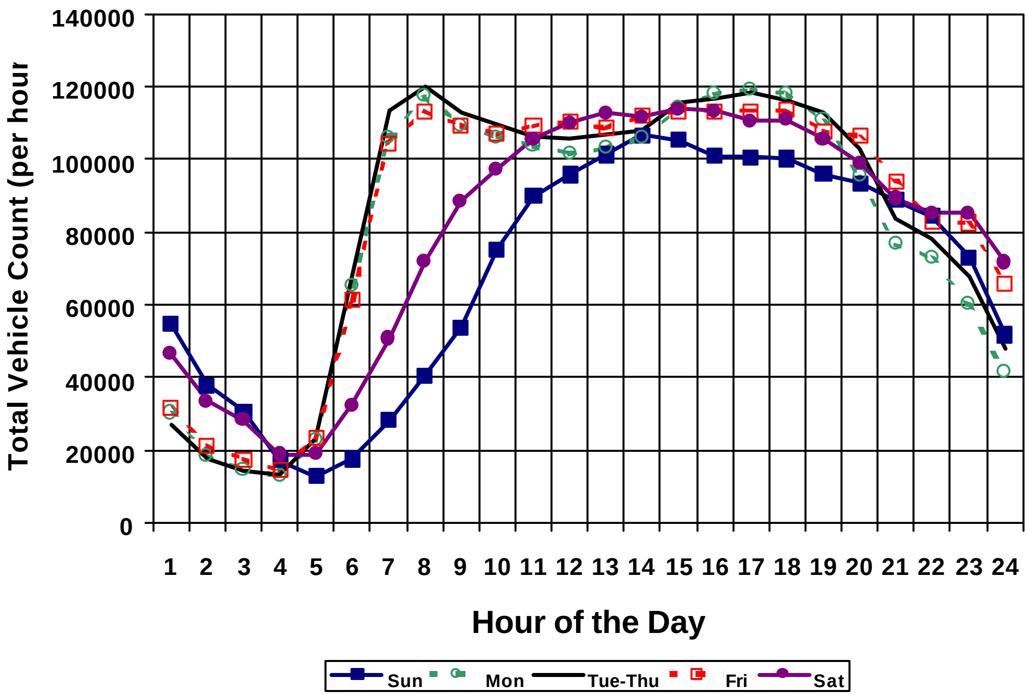


**Figure 5.2.25 Volume Relative to Midweek in the L.A.-CBD Domain**

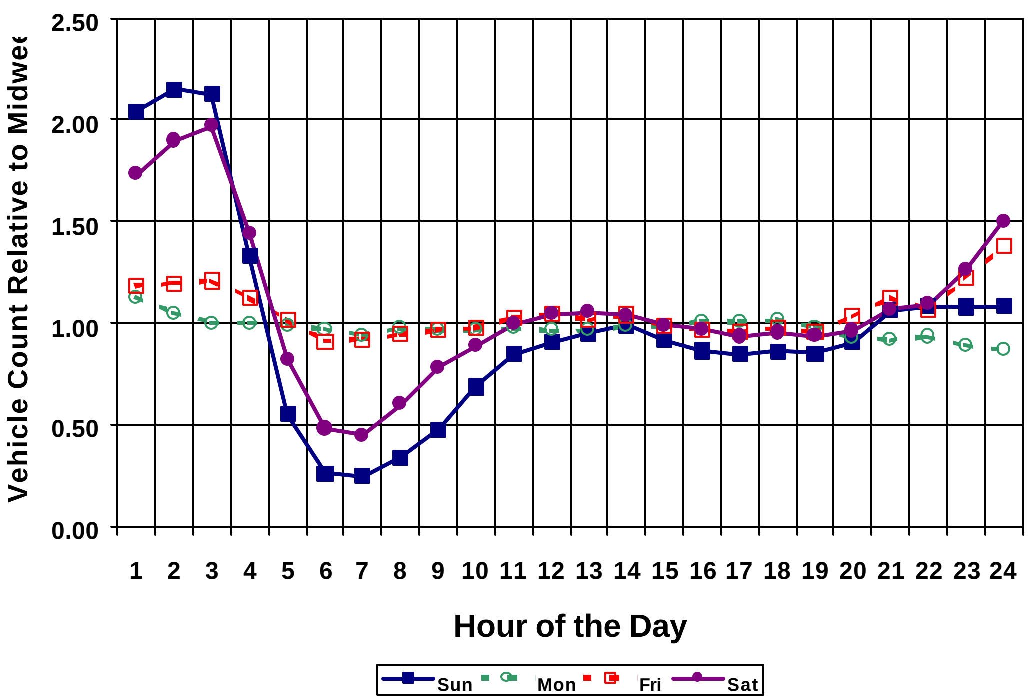

Figure 5.2.26 Total Volume from Selected Counters in the Lynwood Domain

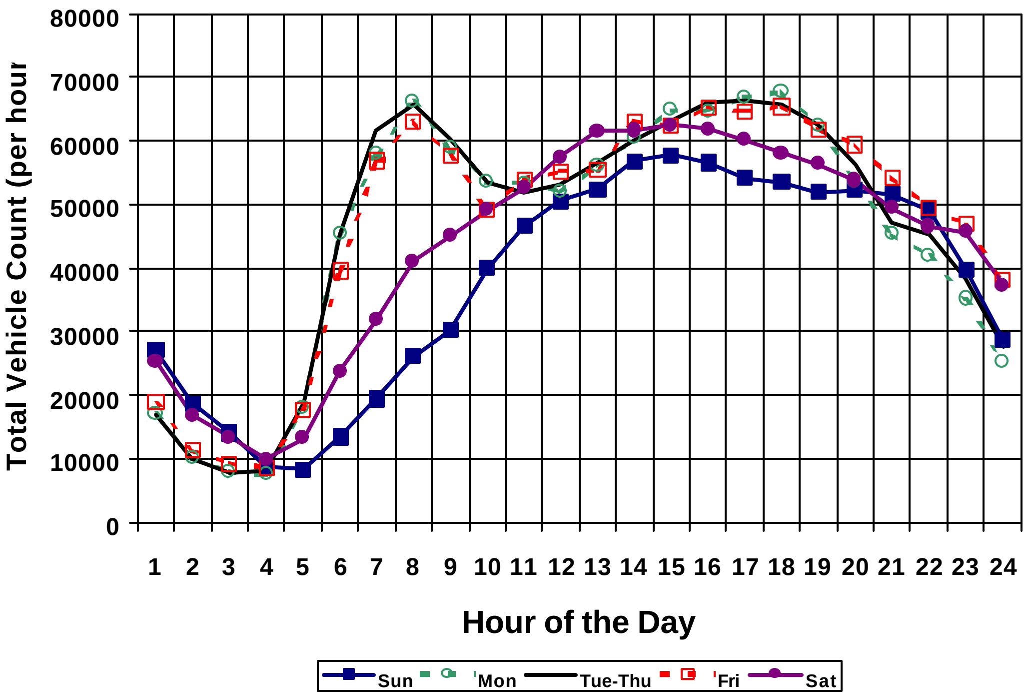


Figure 5.2.27 Volume Relative to Midweek in the Lynwood Domain

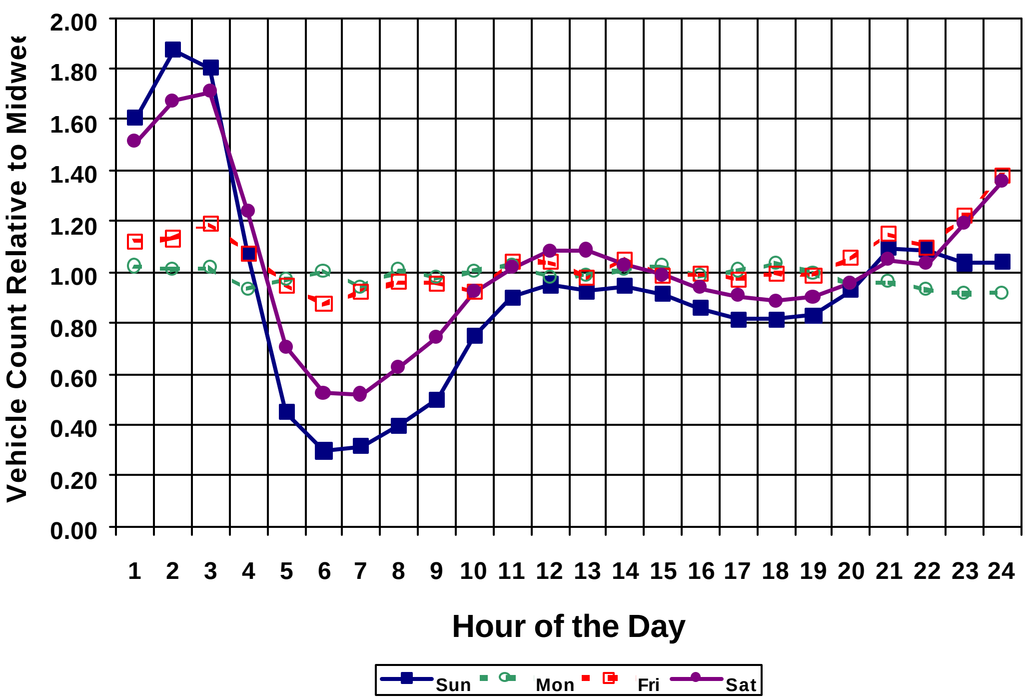

Figure 5.2.28 Total Volume from Selected Counters in the N. Long Beach Domain

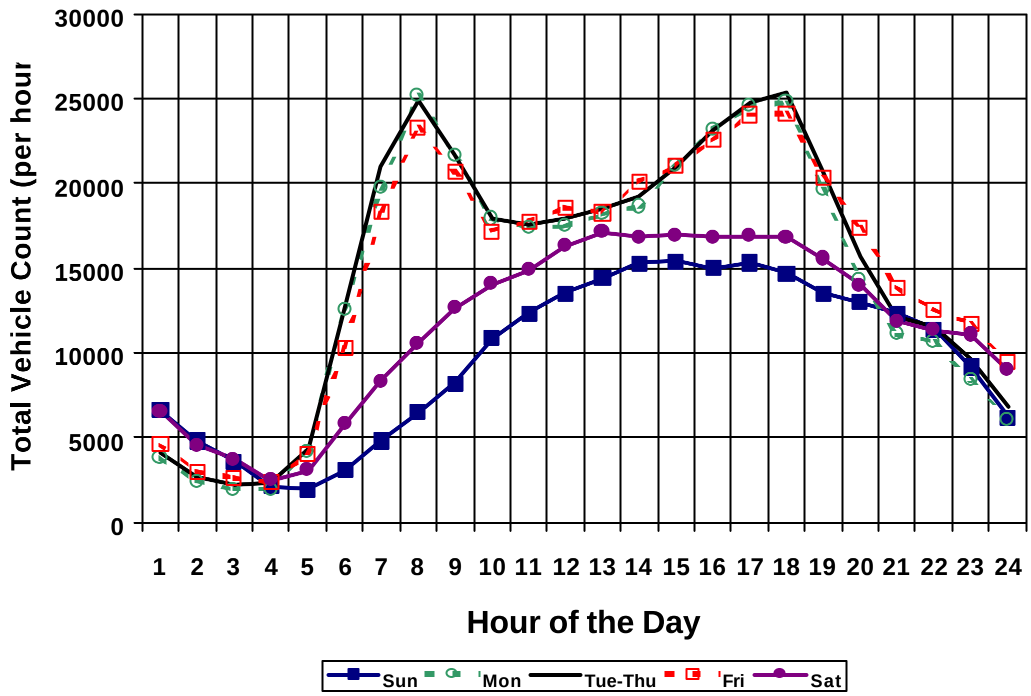


Figure 5.2.29 Vplome Relative to Midweek in the N. Long Beach Domain

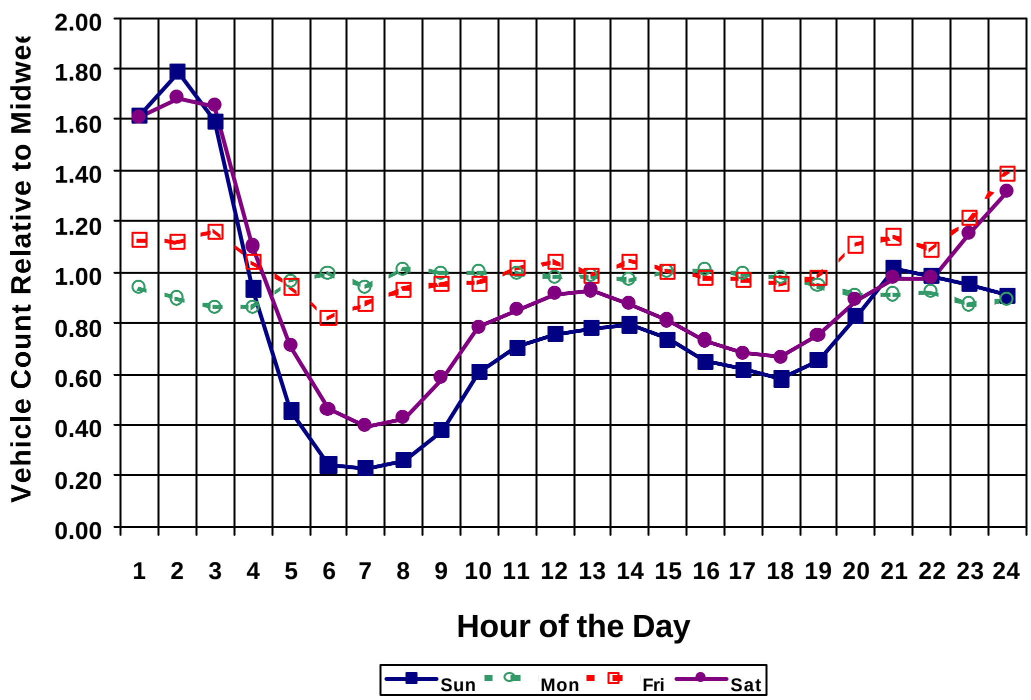

**Figure 5.2.30 Total Volume from Selected Counters in the Pico Rivera Domain**

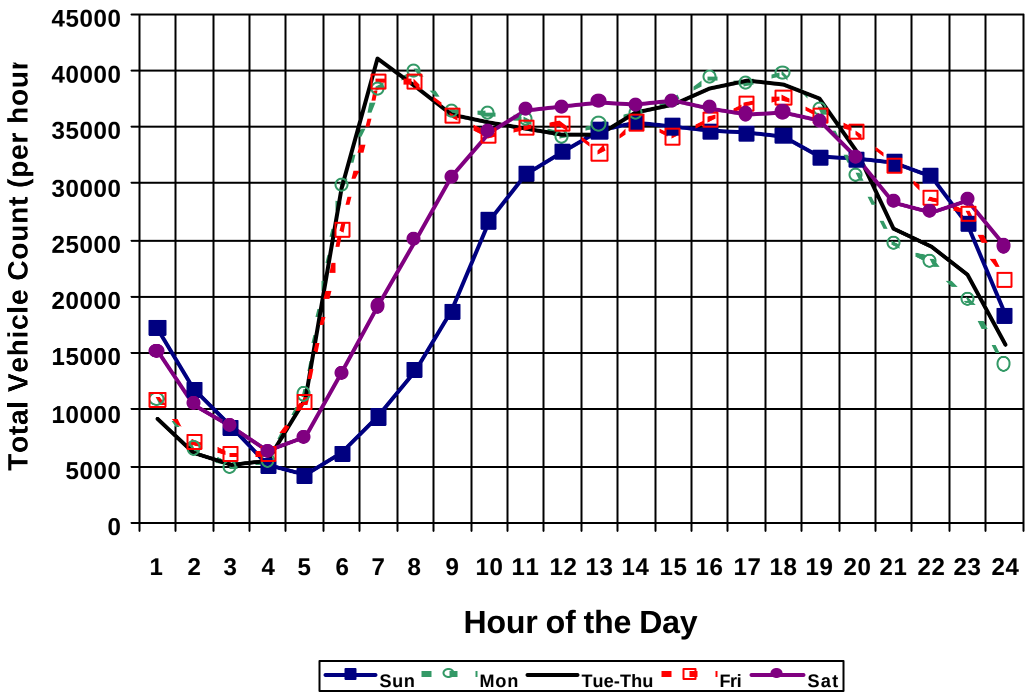


**Figure 5.2.31 Volume Relative to Midweek in the Pico Rivera Domain**

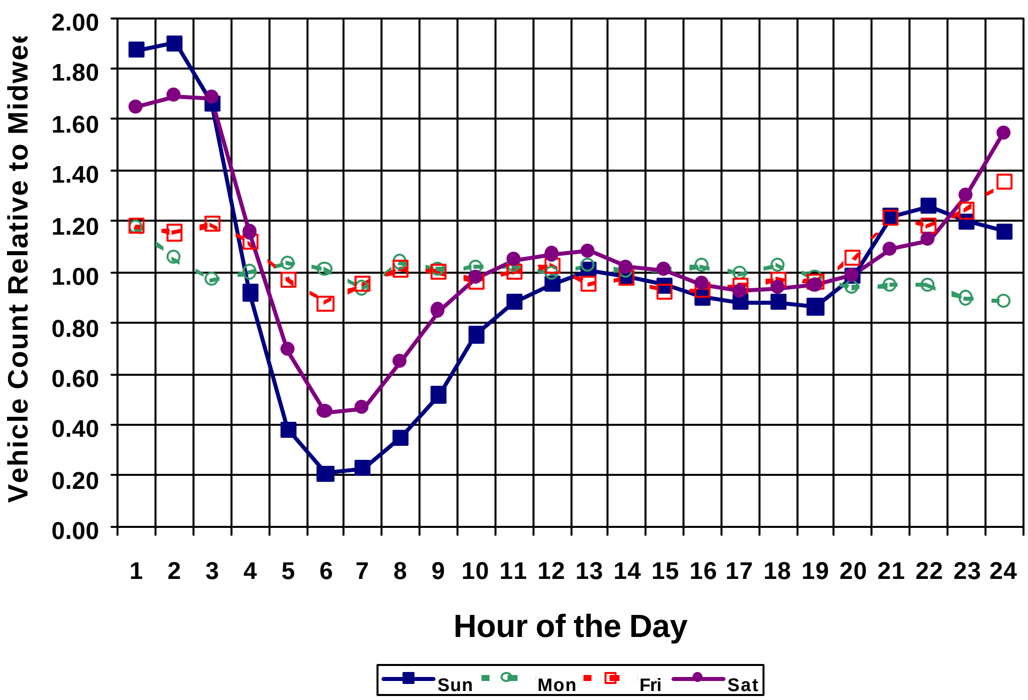

**Figure 5.2.32 Total Volume from Selected Counters in the Pomona Domain**

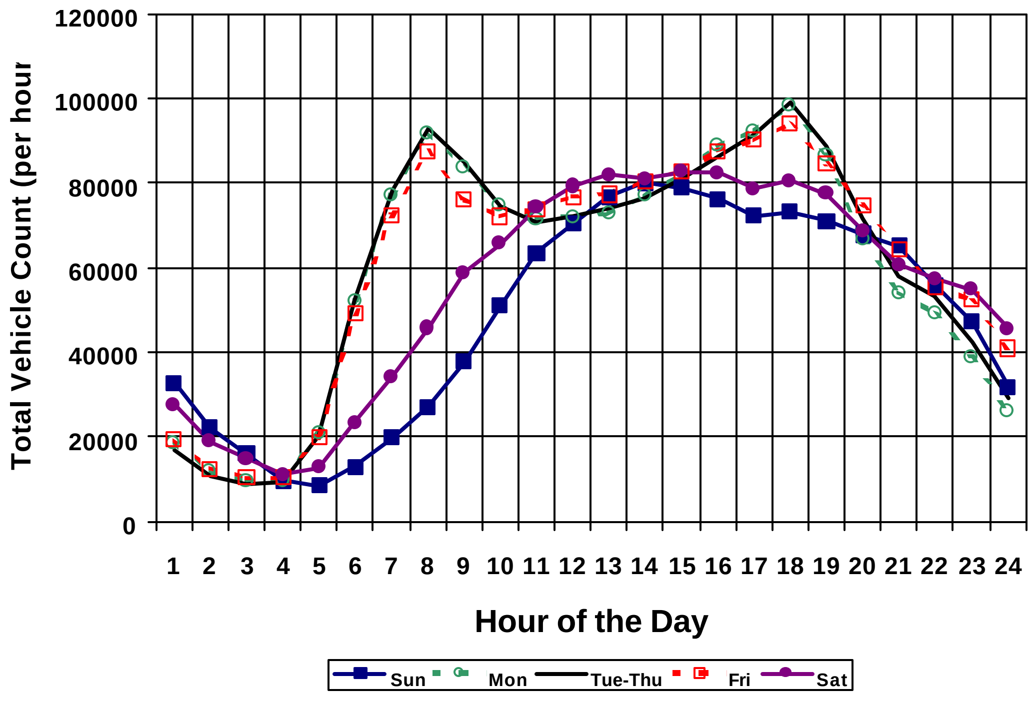


**Figure 5.2.33 Volume Relative to Midweek in the Pomona Domain**

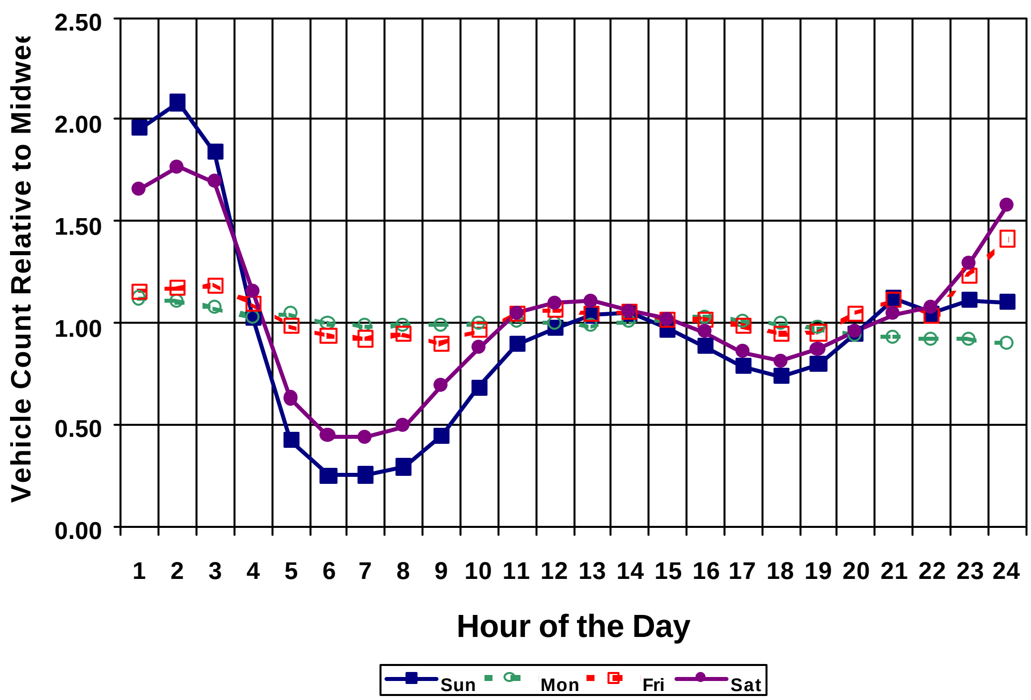

Figure 5.2.34 Total Volume from Selected Counters in the Reseda Domain

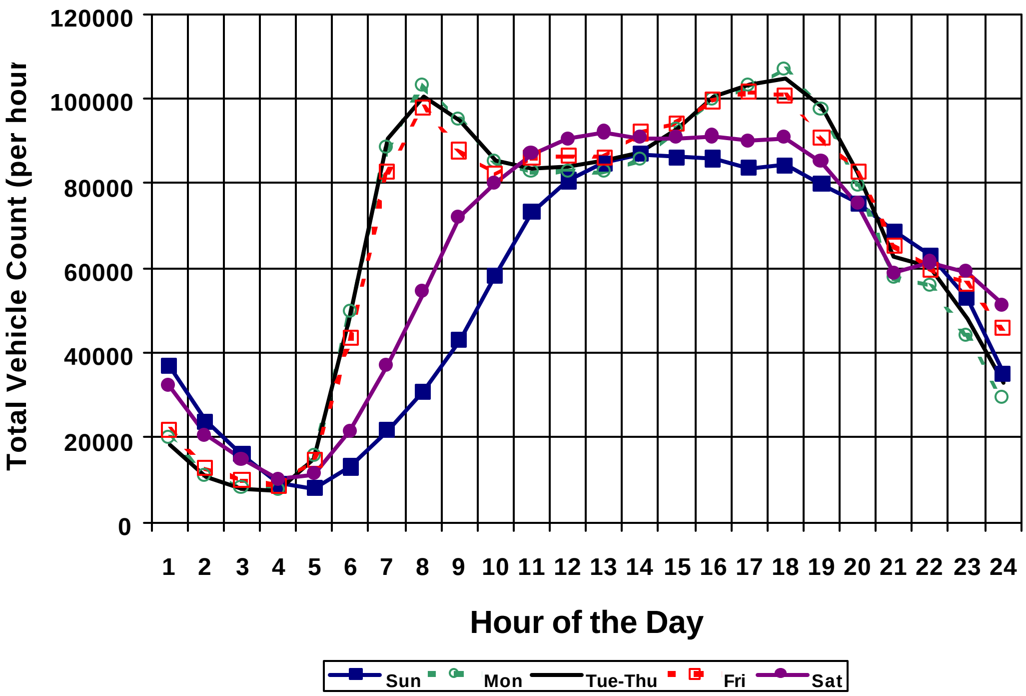


Figure 5.2.35 Volume Relative to Midweek in the Reseda Domain